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AERODYNAMIC NOMENCLATURE AND  
FORMULAS, CONVERSION FACTORS AND  
DRAG FUNCTIONS

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AERODYNAMIC NOMENCLATURE AND FORMULAS,  
CONVERSION FACTORS AND DRAG FUNCTIONS.

In the treatment of projectile aerodynamics, the Proving Ground in the past has employed certain terms and definitions. It has been discovered that many of them are at variance with current aerodynamic usage. The present paper proposes a system which will be more nearly in accordance with it.

Part I is the proposed list of terms. Most of the symbols agree with those in Chapter X of Lt. Col. T. J. Hayes' "Elements of Ordnance", which is now being published.

Part II gives some important formulas, which indicate the relations among the symbols and serve to define certain terms. This part also indicates the assumed standard atmospheric conditions at the surface of the earth.

Part III contains conversion factors pertaining to the new and old symbols, and also to the symbols used by R. H. Fowler, E. G. Gallop, C. N. H. Lock, and H. W. Richmond in "The Aerodynamics of a Spinning Shell" (Phil. Trans. Royal Soc. London. A 221: 295-387). In this report, the new symbols pertain to values expressed in consistent units; the old symbols, in practical units.

Part IV gives the forms of the six types of projectile for which drag functions have been tabulated. Whenever a symbol denotes a particular value pertaining to one of these types, the corresponding number will be added as a subscript.

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## PART I

## AERODYNAMIC NOMENCLATURE

<u>Symbol</u>	<u>Nomenclature</u>	<u>Unit</u>
R	Total air resistance	lb.ft/sec <sup>2</sup>
D	Drag	"
L	Cross wind force	"
N	Normal force	"
M	Moment of R about C.G.	lb.ft <sup>2</sup> /sec <sup>2</sup>
Hw	Yawing moment	"
f	Yawing moment damping factor	sec <sup>-1</sup>
x	Cross wind force damping factor	"
w	Angular velocity of axis of shell	"
$\rho$	Air density	lb/ft <sup>3</sup>
$v_0$	Muzzle velocity	ft/sec
v	Velocity of projectile relative to gun	"
u	Velocity of projectile relative to air	"
w	Velocity of air relative to gun	"
a	Velocity of sound waves in air	"
d	Caliber	ft
m	Mass of projectile	lb
i	Form factor	1
j	Drift factor	1

<u>Symbol</u>	<u>Nomenclature</u>	<u>Unit</u>
1/n	Twist of rifling	1/cal.
N	Spin	sec <sup>-1</sup>
A	Axial moment of inertia	lb.ft <sup>2</sup>
B	Transverse moment of inertia	"
p	Moment of inertia factor	1
s	Stability factor	1
g	Distance from base to center of gravity	cal.
h	Distance from base to center of pressure	"
$\lambda$	Cross wind force factor	lb.ft/sec <sup>2</sup>
$\nu$	Normal force factor	"
$\mu$	Moment factor	lb.ft <sup>2</sup> /sec <sup>2</sup>
k	Retardation coefficient	ft <sup>-1</sup>
$\sigma_1$	Cross wind factor	"
$\sigma^2$	Couple factor	ft <sup>-2</sup>
C	Ballistic coefficient	lb/ft <sup>2</sup>
C <sub>L</sub>	Drift coefficient	sec <sup>3</sup> /ft <sup>2</sup>
K <sub>D</sub>	Drag coefficient	1
K <sub>L</sub>	Cross wind force coefficient	1
K <sub>N</sub>	Normal force coefficient	1
K <sub>M</sub>	Moment coefficient	1
K <sub>H</sub>	Yawing moment coefficient	1
G	Drag function	ft/sec
Q	Drift function	sec <sup>2</sup> /ft <sup>2</sup>

<u>Symbol</u>	<u>Nomenclature</u>	<u>Unit</u>
$\delta$	Yaw	deg.
$\varphi$	Orientation	"

## PART II

### AERODYNAMIC FORMULAS

$$R = (D^2 + L^2)^{1/2}$$

$$D = \rho d^2 u^2 K_D = k \mu u^2$$

$$L = \lambda \sin \delta$$

$$\lambda = \rho d^2 u^2 K_L = \kappa \mu u = c_L \mu u^2$$

$$N = \nu \sin \delta = D \sin \delta + L \cos \delta \text{ (Normal force)}$$

$$\nu = \rho d^2 u^2 K_N$$

$$M = (h - g) dN = \mu \sin \delta$$

$$\mu = \rho d^3 u^2 K_M = c^2 B u^2$$

$$K_M = (h - g) K_N$$

$$N = 2\pi v_o / nd \text{ (Spin)}$$

$$s = \frac{A^2 N^2}{4 B \mu} = \frac{A^2 N^2}{4 B \rho d^3 u^2 K_M} = \frac{\pi^2 A^2}{\rho n^2 d^5 B K_M} \text{ (for } u = v_o \text{)}$$

$$\omega = (\dot{\delta}^2 + \dot{\varphi}^2 \sin^2 \delta)^{1/2} \text{ (Angular velocity of axis)}$$

$$H = \rho d^4 u K_H = f B$$

$$Q = D / \rho d^2 u = u K_D$$

$$Q = K_L / K_M u^2$$

$$C = m / I d^2$$

$$C_L = n / 2\pi g p j v_o$$

$$p = A / nd^2$$

Standard atmospheric conditions at surface;

Barometric pressure: 750 mm Hg (29.53 in Hg)

Temperature: 15° C (59°F)

Relative humidity: 78%

Density: 1.2034 kg/m<sup>3</sup> (0.07513 lb/ft<sup>3</sup>) (525.9 gr/ft<sup>3</sup>)

Velocity of sound: 341.46 m/sec (1120.27 ft/sec)

PART III

CONVERSION FACTORS

New coefficients: non-dimensional, with d in ft,  $\rho$  in lb/ft<sup>3</sup>

Old coefficients: practical units, with d in in.  $\rho$  relative to standard.

Fowler's coefficients: non-dimensional, with radius in ft.  
 $\rho$  in lb/ft<sup>3</sup>.

<u>Symbol</u>	<u>New</u>	<u>Old</u>	<u>Fowler's</u>
	<u>d (ft)</u>	<u>d (in)</u>	<u>r (ft)</u>
d (ft) =	1	.08333	2
d (in) =	12	1	24
r (ft) =	0.5	.04167	1
	<u><math>\rho</math> (lb/ft<sup>3</sup>)</u>	<u><math>\rho</math> (relative)</u>	<u><math>\rho</math> (lb/ft<sup>3</sup>)</u>
$\rho$ (lb/ft <sup>3</sup> ) =	1	.07513	1
$\rho$ (relative) =	13.31	1	13.31
	<u>K<sub>D</sub></u>	<u>C<sub>R</sub></u>	<u>f<sub>R</sub></u>
K <sub>D</sub> =	1	1916.8	.25
C <sub>R</sub> =	52.17 x 10 <sup>-5</sup>	1	13.04 x 10 <sup>-5</sup>
f <sub>R</sub> =	4	7667	1
	<u>K<sub>L</sub></u>	<u>C<sub>λ</sub></u>	<u>f<sub>L</sub></u>
K <sub>L</sub> =	1	1916.8	.25
C <sub>λ</sub> =	52.17 x 10 <sup>-5</sup>	1	13.04 x 10 <sup>-5</sup>
f <sub>L</sub> =	4	7667	1

<u>Symbol</u>	<u>New</u>	<u>Old</u>	<u>Fowler's</u>
	<u><math>K_N</math></u>	<u><math>C_N</math></u>	<u><math>r_N</math></u>
$K_N =$	1	1916.8	.25
$C_N =$	$52.17 \times 10^{-5}$	1	$13.04 \times 10^{-5}$
$r_N =$	4	7667	1
	<u><math>K_M</math></u>	<u><math>C_M</math></u>	<u><math>r_M</math></u>
$K_M =$	1	$.2300 \times 10^5$	.125
$C_M =$	$4.348 \times 10^{-5}$	1	$.5435 \times 10^{-5}$
$r_M =$	8	$1.840 \times 10^5$	1
	<u><math>K_H</math></u>	<u><math>C_H</math></u>	<u><math>r_H</math></u>
$K_H =$	1	$2.760 \times 10^5$	.0625
$C_H =$	$.3623 \times 10^{-5}$	1	$.02264 \times 10^{-5}$
$r_H =$	16	$44.16 \times 10^5$	1

#### PART IV

#### DRAG FUNCTIONS

Type Proj.	<u>Drag Function</u>		Base	Point
	<u>New</u> <u>Symbol</u>	<u>Old</u> <u>Symbol</u>		
1	$G_1$	G	Square	About 2 cal. radius ogive
2	$G_2$	J	6° boat-tail	Long ogive-conical head
3	$G_3$	$J_3$	Square	Scovill fuze Mark III
4	$G_4$	$J_4$	7.5° boat-tail	Long P.D. fuze Mark III
5	$G_5$	$J_5$	7.5° boat-tail	Short P.D. fuze Mark V
6	$G_6$	$J_6$	Square	7 cal. radius ogive

Note: The tabulated drag functions are in practical units.

Multiply by 1916.8 to obtain

$$Q = uK_D$$

where  $K_D$  is non-dimensional.

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